

## Description

# INTRAOCULAR LENS WITH AN ACCOMMODATING CAPABILITY

### BACKGROUND OF INVENTION

- [0001] The present invention relates generally to an intraocular lens and, in particular, an intraocular lens with accommodating capability.
- [0002] An intraocular lens (IOL) is a surgical device, which can be implanted into the eye to replace cloudy natural lens during cataract surgery. However, the artificial lens is different from the natural lens, which can change shape to facilitate accommodation of the eye. Therefore, almost every patient needs reading glasses for near work after cataract surgery.
- [0003] IOLs are known with accommodating capabilities. Currently, a number of different approaches have been attempted for designing an accommodating IOL, such as forward movement of lens optic, curvature change of the lens optic, and change of refractive index of the lens op-

tic.

## **SUMMARY OF INVENTION**

[0004] In accordance with a broad aspect of the present invention there is provided an IOL comprising: an optic; a haptic; a flexible membrane substantially encircling the optic and connected between the optic and the haptic. The flexible membrane has a flexibility greater than the optic and greater than the haptic.

## **BRIEF DESCRIPTION OF DRAWINGS**

[0005] Figure 1A is front elevation of an intraocular lens.

[0006] Figure 1B is front elevation of another intraocular lens.

[0007] Figures 1C to 1E are side elevations of the intraocular lens of Figure 1A showing its positions during accommodation, wherein Figure 1C is at rest and Figures 1D and 1E are undergoing accommodation by forward movement of the lens optic.

[0008] Figure 2A is front elevation of another intraocular lens.

[0009] Figure 2B is front elevation of another intraocular lens.

[0010] Figures 2C to 2E are side elevations of the intraocular lens of Figure 2A showing its positions during accommodation, wherein Figure 2C is at rest, Figure 2D is at a stage of ac-

commodation and Figure 2E is at a further stage of accommodation.

[0011] Figure 3A is front elevation of another intraocular lens.

[0012] Figures 3B to 3D are side elevations of the intraocular lens of Figure 3A showing its positions during accommodation, wherein Figure 3B is at rest and Figures 3C and 3D are at progressive stages of accommodation.

[0013] Figures 4A and 4B are front and side elevations, respectively, of lens optics useful in the present invention.

[0014] Figures 4C to 4F are side elevations of further lens optics useful in the present invention.

#### **DETAILED DESCRIPTION**

[0015] In one embodiment, an IOL may provide accommodating capability by forward movement in the eye, varying the distance of the IOL or lens optic from the retina, and/or curvature change of the lens optic. To achieve these affects, the IOL may make use of the forces of zonule tension from ciliary muscle contractions. In addition, vitreous forces may act upon the IOL. Vitreous forces are also reliant, at least in part, on ciliary muscle contractions wherein such contractions result in posterior bulking within the eye, which decreases the volume of the vitreous

cavity. Since the vitreous volume is fixed, the pressure on the contraction of the ciliary muscle cause vitreous movement wherein the peripheral vitreous is pushed back and the central vitreous moves oppositely and, therefore, forwardly. Consequently, the movement of the vitreous may push the lens optic forward in the eye. It appears that forward movement of the lens optic must be significant in order to adjust the lens power for example to provide near vision. However, minor curvature changes on the lens optic appear to change the lens power significantly.

[0016] An IOL providing accommodation by forward movement in the eye and/or curvature change of the lens optic is shown in Figure 1A and 1C to 1E. In one embodiment, an IOL 10a includes a lens optic 12a and a haptic 14a. As is known, lens optic 12a provides for the corrective refraction of light for focusing to the retina, while haptic 14a is a supporting structure for mounting the optic in the capsular bag. Haptic 14a includes mounting points 18a, which engage against the capsular bag.

[0017] The lens optic is secured to the haptic through flexible, elastomeric membranes 16a. Membranes 16a together at least substantially encircle optic 12a. Each membrane has a flexibility greater than that of the surrounding materials.

In particular, each membrane 16a has a flexibility greater than that of either lens optic 12a or haptic 14a. Flexibility may be achieved by selection of materials or, as in the illustrated embodiment, by selection of the thickness of the membrane relative to the surrounding parts. For example, the membranes may be formed thinner and possibly much thinner than the haptic to render it more flexible than that part. While two membranes are shown, it is to be understood that one substantially circular membrane may be employed, if desired. Alternately, further membranes may be positioned such that they together encircle optic 12a. For example, with reference to Figure 1B, an IOL is shown including four membranes 16b about optic 12a.

[0018] The membranes are able to flex to permit movement of optic 12a relative to haptic 14a, in response to the application of force to optic 12a. The membranes, however, are resilient such that they are biased towards their original form as the application of force is diminished or discontinued.

[0019] Haptic 14a may be formed in various ways to mount the IOL in the posterior chamber or the anterior chamber of an eye and to support the membranes 16a and therethrough lens optic 12a. While other haptic forms can

be used as desired, in the illustrated embodiment, haptic 14a is a plate haptic including an upper half 20a' and a lower half 20a". The haptic includes a membrane support ring formed of segments 21. In particular, each of the upper half and the lower half of the haptic includes a ring segment 21 that extends the haptic upwardly around the optic to support membranes 16a. In the illustrated embodiment, ring segments 21 frame the membranes 16a to offer support for the membranes at their outer edges.

Ring segments 21 may be formed as a part of the haptic or separately therefrom with a connection to the haptic.

[0020] Membranes 16a may be mounted at or close to the optic's largest diameter side edges 23 (see Figures 4) and each membrane extends along a section of the circumference about the optic such that membranes 16a together substantially encircle the optic. The membranes may be independent from each other, for example in one embodiment separated by slits or gaps 22. In the illustrated embodiment, the IOL includes two membranes 16a about the optic, with each membrane being continuous between its ends and extending substantially about one half the optic circumference. The membranes are spaced apart at each of their ends to form gaps 22 therebetween. The gaps

may, for example, be positioned on the sides of the IOL between the haptic mounting points 18a.

[0021] Haptic 14a may also be discontinuous, for example by forming the upper half 20a' separate from the lower half 20a", for example, at a split or gap 24 adjacent to gaps 22 between membranes 16a.

[0022] Gaps 22 and 24 reduce stiffness and resistance to bending for the IOL wherein only the optic provides stiffness between the upper half and the lower half of the haptic. As such, when the ciliary muscle contracts to change the zonule tension and increase the vitreous pressure, the IOL can easily bend between gaps 22 and 24. Furthermore, where gaps 22, 24 are used that space the surrounding parts, the gaps can allow for greater range of motion to facilitate depth movement of the optic as the parts do not readily bear against each other. Gaps 22, 24 also permit dimensional expansion of the IOL wherein the diameter  $D_r$  of the IOL at rest (Figure 1C) may be extended to diameter  $D_e$  wherein the IOL is expanded about gaps 22, 24 (Figure 1D). The expansion to diameter  $D_e$  facilitates travel of optic 12a to thereby facilitate accommodation.

[0023] In an IOL having more than two membranes, as in Figure 1B, gaps 22a, 24a may be formed between each mem-

brane 16b and between each ring segment 21a. The ring segments 21a may be extended about the membranes 16b to support them on their outer edges.

[0024] The surface area of optic 12a and membranes 16a also act to trap vitreous fluid as it is moved within the eye by ciliary muscle contractions. The form of membranes 16a act to trap the fluid pressure and this creates a force, arrows F, that acts with the flexibility of membranes 16a to drive forward movement of the optic.

[0025] In operation, when the ciliary muscle contracts, vitreous pressure will increase and act on the posterior surface area of the lens optic and membranes 16a to push the lens optic forward as shown progressively from Figure 1C where the IOL is at rest through the position of Figure 1D to the position of Figure 1E. In addition, such movement of optic 12a and membranes 16a changes the pressure exerted at side edges 23 of the optic by the membranes. This causes the optic curvature to be changed. When the ciliary muscle relaxes, the vitreous pressure is released and the lens optic will return to its original form (Figure 1C) and position because of material elasticity. A combination of forward movement and lens optic curvature change may provide the eye with significant accommodat-



ing power to focus on near objects.

[0026] The membranes can be formed at an angle to the optic to enhance their effect on optic curvature change when force is applied thereto. In one embodiment, the membranes together form a frustoconical surface formed at an angle  $\alpha$  of 5 to 15 degrees or possibly 10 to 15 degrees from a plane defined through the optic side edges 23. An increase in angle  $\alpha$  increases the degree to which optic 12a can travel. Consequently, it may add more positive power for near vision.

[0027] The IOLs can be made from various materials, as would be appreciated by a skilled person. For example, the materials for the optic and possibly for other parts are clear and compatible for use in the body. The materials are selected and formed to be sufficiently stiff to retain the IOL form and position in the eye, but to be flexible to react to muscle contractions and vitreous fluid pressure. Where a foldable lens is useful, foldable materials such as silicone, acrylic, hydrogel, etc. may be used. One-piece construction may also be useful. In the illustrated embodiment a one-piece construction is used wherein the haptic, ring segments, membranes and optic are formed integral.

[0028] Lens optics useful in the present invention may vary, as

desired. For example, a liquid form optic, as shown in Figures 1A and 2A, or a solid form optic 12d, as shown in Figures 1B, 2B and 3A can be selected for the lens optic. Some useful optic forms are shown in Figures 4. For example, as shown in Figures 4A and 4B, a liquid lens optic 12a may be used. Such a lens optic may include an outer capsule 26 forming an inner chamber 28 that may be filled with liquid material such as silicone or other liquid and clear materials. The lens capsule may be thinned centrally with an increasing peripheral thickness, as shown in Figure 4B. In other embodiments, a lens optic 12b may be used wherein the lens capsule 26a may be more uniformly thick (Figure 4C), a lens optic 12c may be used wherein the lens capsule 26b can include one thicker side (Figure 4D). Capsule design can be selected to control lens optic shape change and thereby curvature changes resulting from application of pressure. A liquid lens tends to have greater flexibility of a solid lens. Solid optics may include, for example, an optic 12d (Figure 4E) including a form generally symmetrical about its edges 23 or an optic 12e (Figure 4F) that is curved assymmetrically on either side of its side edges 23. If a solid optic is selected, soft and flexible materials may be used to construct the optic in

order to facilitate curvature change.

[0029] It is to be understood that while a particular haptic form is shown, other haptic forms may be used as desired such as, for example, as shown in Figures 2A to 2D, a frog leg form haptic 14b, such as is disclosed in applicant's corresponding US published patent application 10/248,917 or a running leg form, also disclosed in the aforementioned patent application. In another embodiment, an alternate plate form, known as a pie shaped haptic 14d may be used such as is shown in Figures 3A to 3D. In an IOL having a pie shaped haptic, membranes 16b are mounted along their outer edges to haptic 14d. Gaps 22b may be provided between the membranes and gaps 25 may be formed in the haptic adjacent gaps 22b to provide the flex about gaps described hereinabove. Although not shown, a ring may be positioned or formed between membranes 16b and haptic 14d, if desired, for additional support of the membranes.

[0030] It will be apparent that many other changes may be made to the illustrative embodiments, while falling within the scope of the invention and it is intended that all such changes be covered by the claims appended hereto.